

X-Ray Timing and Jets: The Future

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Abstract.

I discuss some potential contributions of future X-ray timing missions to understanding relativistic jet systems. I focus particularly on stellar-mass black hole systems, as other authors in this proceedings cover AGN, etc.

1. INTRODUCTION

The first thing to establish in what X-ray timing can tell us about relativistic jets is: “what do we want to know?”. I think there are three key issues for the immediate future of jet studies:

- **What are jets made of?** Are they electron-positron (implied by 511-keV emission from 1E1740-2947)? Are they electron-proton (definitely seen in SS433)? Does Poynting flux dominate the jet energy?
- **How do compact objects make/accelerate relativistic jets?** Is MHD *the* only way? Is the magneto-rotational instability important? Are rotating black holes necessary, helpful, or irrelevant?
- **How do the jets differ from system to system?** This question can and should be asked both among and between stellar-mass black holes, supermassive black holes, rotating versus non-rotating black holes, and neutron star systems.

I give a (by no means exhaustive) breakdown of the detailed questions we can attempt to answer for jet systems using X-ray timing:

1. **How often** are the jet systems active?
2. **How often** are jets ejected during an active phase?
3. **How fast** do they rise?
4. **How fast** do they fade?
5. **How fast** do they change brightness (including flares, spikes, QPOs, etc.)?
6. **How fast** do they change their spectrum?
7. **How** does this behavior relate to non-X-ray bands (i.e. radio, optical, IR)?
8. **How** do these vary from system to system?

In attempting to answer these questions, I will address three general types of future X-ray timing instruments:

- A wide-field (“all-sky”) instrument
- A very large-collecting-area instrument (e.g. a “super” version of the PCA on RXTE)
- A high spectral-resolution instrument

2. WIDE-FIELD X-RAY INSTRUMENT

One crucial area enabled by an “all-sky”-type instrument is understanding the long-timescale variability in these systems. This includes their outburst frequency and duty cycle, neither of which are well-understood in ANY relativistic jet source. We also have only started scratching the surface for observations of long-term spectral state evolution, as well as variations from outburst to outburst within a single system. Such observations will help determine the “long” timescales associated with jet production. They will also provide insight into what “refueling” is necessary for jet production in transient jet systems. Hand-in-hand with this understanding, we require further insight into the basic accretion processes themselves (a recurring theme throughout this talk).

A next-generation all-sky monitor could also observe much faster timescales in bright sources. For instance, some proposed missions could study the microquasar GRS 1915+105 on a level of detail in the lightcurve approaching the RXTE PCA (at least for identifying and timing the various types of variability seen from this system). This would also provide our first **continuous** look at the various states and behaviors in these systems, and allow us our first comprehensive look at the state transitions in fine detail.

An all-sky monitor could also serve as a trigger for pointed and/or multi-wavelength observations of be-

haviors of particular interest for understanding jets. A tremendous amount of progress in understanding jets has come about in recent years by studying transient activity, particularly in multiple wavebands simultaneously. However, this work currently relies on the RXTE/ASM or pure blind luck. So ... a next-generation all-sky monitor is crucial for much multi-wavelength work. This should have increased importance in the coming era of LOFAR in the radio, queue-scheduling of large optical/IR observatories (allowing TOO programs), and robotic IR/optical telescopes dedicated to transient studies. These observations will help determine the detailed link and interaction between the compact object/disk (which is typically X-ray bright) and the newly-formed jet itself (which is typically X-ray faint).

Finally, an all-sky monitor is the most powerful tool for the discovery of new sources. Without such an instrument, we rely on serendipity to find such new systems. New sources have been the lifeblood of this field, especially given the currently very small numbers of known systems. This work addresses essentially every aspect of jets, and is particularly important for investigating the range of behaviors in jet systems and source populations (with implications for evolutionary paths).

In order to accomplish these goals, a next-generation wide-field X-ray timing instrument should have the following characteristics:

- Sky coverage of $\sim 4\pi$ steradians, essentially all the time
- Positional accuracies of ~ 1 -arcminute
- Sensitivity much better than 1 Crab in 1s
- Sensitivity better than 1 milli-Crab in 1 day

3. LARGE-AREA POINTED INSTRUMENT

A large-collecting-area instrument is another key component for future X-ray timing studies of relativistic jets. The PCA on RXTE sees the fine details of X-ray emission from jet sources, for instance. However, some currently-known sources (e.g. SS433) are a bit faint for the PCA. Furthermore, we see broad spectral changes on the fastest timescales for which the PCA has real sensitivity in the microquasar GRS 1915+105. We also see weak high-frequency QPO from jet sources which require rather longish detection times for the PCA – we’d like to know how fast these vary and whether or not fainter/faster QPO are as yet undetected. Thus, we have clear potential for a “super-PCA” to help us determine the physics of the X-ray-emitting regions in jet sources. It is exactly these fastest timescales of variability which appear to probe the innermost accretion disk around the

compact object, which is thought to be the “heart” of relativistic jet production.

A large-area instrument would also serve as the X-ray “eye” for multi-wavelength observational campaigns for jet sources. The PCA on RXTE has had great success with this approach for a great variety of systems – yet, there is nothing new to replace it. Also, as noted above, this should have increased importance in the coming era of LOFAR in the radio, queue-scheduling of large optical/IR observatories (allowing TOO programs), and robotic IR/optical telescopes dedicated to transient studies.

Finally, I point out that while an all-sky instrument is crucial for discovery of new sources and transient outbursts, this discovery alone is merely an appetizer. The large-area instrument provides the “meat and potatoes” X-ray observations which fill our bellies with new scientific content to grow and maintain a healthily-progressing scientific field.

In order to accomplish these goals, a next-generation pointed large-collecting-area X-ray timing instrument should have the following characteristics:

- Sensitivity much better than 1 milli-Crab in 1s
- Time-resolution less than $\sim 1\mu s$
- Energy resolution of $\frac{E}{\delta E} \sim 20 - 50$
- Field-of-view > 30 -arcminute
- If possible, position resolution of ~ 1 -arcminute (reducing background and confusion issues)

4. HIGH SPECTRAL-RESOLUTION INSTRUMENT

A high-resolution spectral instrument is also important for helping understand relativistic jet sources. It has been said that if a picture is worth a thousand words, then a spectrum is worth a thousand pictures. This has not always been apparent in the field of X-ray timing, but I think it is likely to develop rapidly in coming years. The RXTE PCA, for instance, sees rapid spectral variability from some jet sources, but lacks the spectral resolution for proper line studies. Meanwhile, XMM and *Chandra* have good spectral resolution, but lack adequate (sub-second) time resolution and/or dynamic range. This work can illuminate the physics of the X-ray-emitting regions of jet sources, especially the iron-line and other important disk diagnostics. As noted above, these regions are thought to be the “heart” of jet production in these systems.

In order to accomplish these goals, a next-generation high-spectral-resolution X-ray timing instrument should have the following characteristics:

- Sensitivity much better than XMM

- Time resolution $< 0.1s$
- Energy resolution of $\frac{E}{\delta E} \sim 100 - 500$
- High dynamic range (so that it doesn't saturate on interesting sources)
- If possible, position resolution of ~ 1 -arcminute (reducing background and confusion issues)

5. CONCLUSIONS

There has been a rather brief, and undoubtedly incomplete, review of the promise of next-generation X-ray timing missions for understanding relativistic jet sources. The key points I would like to emphasize are:

- There is an awful lot yet to be learned from X-ray timing of jet sources – “static” instruments alone are insufficient for studying these dynamic systems.
- A wide-field (“all-sky”) instrument may be the highest priority. It can do a fair amount of stand-alone science, while others rely on this instrument (or blind luck) as a “finder” for key events and new sources.

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